# Draft on Chapter 2 – Charm correlation

Results reported at the recent QM05 conference on the nuclear modification factor $R_{AA}$ indicate that the heavy-quark energy loss in central Au+Au collisions is similar to that of the light-quarks (u, d, s). Since there is no directly reconstructed heavy-quark hadron distributions in experiments at RHIC, the electron $R_{AA}$ was used for the heavy-quark study for the electron transverse momentum range: $4 < p_T < 10$ GeV/c. This experimental observation contradicts our early understanding of the pQCD interactions of energetic partons in hot and dense medium where much less energy loss is expected for heavy-quarks compared with the light ones [Kharzeev1,Gyulassy1,Armesto1]. When analysis the data with only electron $p_T$ distributions, the issue is further complicated by the unknown mixture of charm and beauty contributions in heavy-ion collisions at RHIC energies. Reconstructed charmed-hadron distributions and angular correlations are absolutely needed in order to detangle the important problem at RHIC.

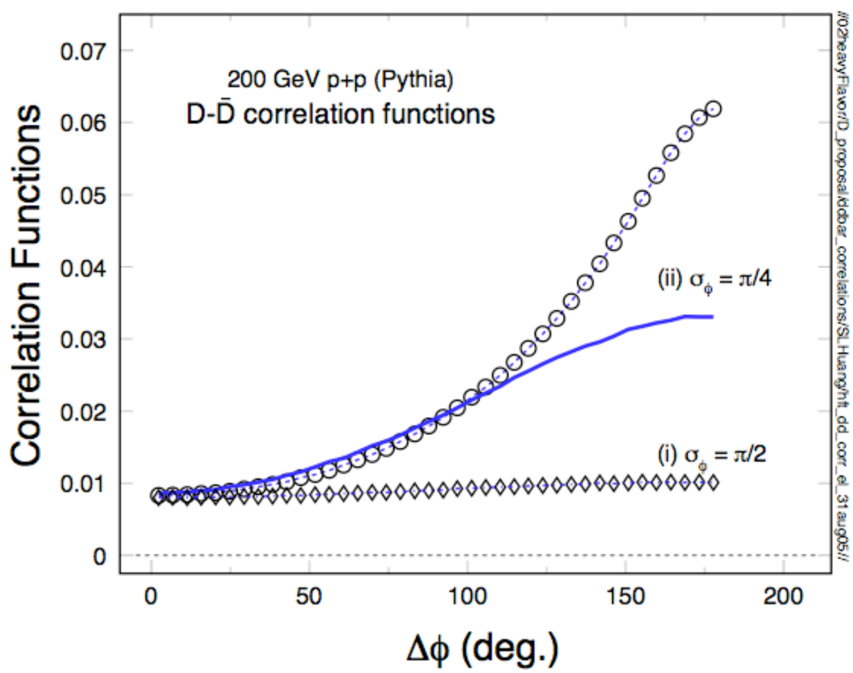


**Figure 1:** D-meson correlation functions from 200 GeV p+p collisions. Default parameters in the Pythia model [1] were used in the calculations. A clear back-to-back correlation in the charmed meson production is observed. Solid-line and diamonds represent the results with angular smearing for $\sigma_\phi = \pi/4$ and $\pi/2$, respectively.
without energy loss, respectively.

Heavy-quark angular correlation: Similar to jets production, heavy-quark production requires large momentum transfer therefore one expects a distinct back-to-back topology. Again because their heavy mass, the charm- (or beauty-) hadrons are also formed with the back-to-back structure in elementary collisions as shown in Figure 1 by the open-circles. In this calculation, the Pythia (v6.2) was used with the default sets of parameters. As one can see in the figure, there is a clear back-to-back correlation for the D-mesons. Here we propose to utilized the distingue correlation to study the charm-quark energy loss in high-energy nuclear collisions. In the following, we will discuss three observables:

(i) When a charm-quark interacts with the medium, it will not only loss its energy, the original angular correlation pattern as shown in the figure will also be modified. In Fig. 1, the tests with angular smearing of $<\sigma_\phi> = \pi/4$ and $\pi/2$ shown as solid-line and diamonds are also plotted. In addition, the change of the angular correlation depends on the nature of the interaction. Most of the (semi)elastic scatterings are forwarded [Tai1,Rapp1], while the inelastic scatterings, such as the gluon radiative energy loss [Gyulassy1], would lead to a much wider smearing in the final correlation. In the inelastic scattering scenario [Gyulassy1,Armenstro1], the energy-loss occurs in deep plasma and the final correlation function reflects the hot/dense properties of the medium. On the other hand, the resonant scattering happens at near $T_c$ [Rapp1]. Although both scenarios lead to sizable energy-loss [Gyulassy1,Rapp1], the angular correlations should allow us to distinguish these two different mechanisms in high-energy nuclear collisions. In order to perform the measurement, a large acceptance with the reconstructed charm-hadrons are essential. The proposed HFT, plus STAR TPC and TOF, will be necessary for this study.

(ii) Recently, the measurements on charm production by the Bell Collaboration [Bell] showed a surprising large cross section for $J/\psi$ in sqrt(s)=10.6 GeV e+e collisions. Even more surprising, more than half of the observed $J/\psi$'s were accompanied with ccbar pairs. This result contracts our current understanding for $J/\psi$ production in the pQCD framework, such as those discussed in Refs. [Pythia, Cho, Baek, Yuan], and implies a different production mechanism for heavy-quarks in elementary collisions [Kharzee2]. As proposed in [Kharzeev2], the gluon fragmentation will become increasingly important for collisions at higher bombarding energies. In elementary collisions, the main difference between the new and conventional processes lies in the angular correlation of the produced charm-hadrons.  With the proposed HFT and STAR EMC (Electro-Magnetic Calorimeter), we will study the correlation to further the pQCD in p+p collisions at RHIC energies. In addition, in high-energy nuclear collisions, gluon density is high [Gyulassy2, Kharzeev4] which might enhance the effect observed in elementary collisions. Such correlation study will certainly shed light on the production mechanisms for charm and charmonium at RHIC.

(iii) As discussed above that heavy-quarks production leads to the correlation between particle and its anti-particles. It also reflected in their decayed products, such as the electron pairs. In this case, it causes the background at the intermediate mass region $1 < m_{ee} < 3$ GeV/c$^2$ [Rapp2]. Here $m_{ee}$ is the invariant mass of the electron pair. Analyzing the correlated electron pairs with the proposed HFT, the charm background will be greatly reduced. More discussion on this will be presented in Section 2.5.

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